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Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

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If no title is shown please refer to the description.
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High-Resolution Magnetic Encoder

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High-Resolution Magnetic Encoder

Field of the Invention

The present invention relates in general to a high-resolution magnetic encoder system. Specifically, the present invention is concerned with such a system that uses GMR or TMR technology.

Background of the Invention

Devices for quantitative detection of linear and rotary movements are known. Optical encoders are used to detect the rotation angle or, respectively, a length and a direction of a rotary movement or, respectively, linear movement of moving bodies. The essential components of such a device are the emitter system, a grid plate, normally a grid disk or a grid straight edge, and the detector system. The emitter system normally contains a light emitting diode (LED). The light beam emitted from the light emitting diode or laser diode is modulated by the grid plate. The grid plate is connected to a moving body and has a periodic opening pattern. The detector system detects the transmitter signal (modulated by the grid plate) from the laser diode and, at the output, supplies information relating to the light beam and the direction of movement.

High-resolution magnetic encoders using Hall sensors are also known. As well, magnetic encoders (magneto-electric converters) which employ a magnetoresistance effect element made of a thin ferromagnetic film, have been commonly used in various fields due to their good durability in a surrounding atmosphere, wide operational temperature range and high response frequency. For example, magnetic encoders are used for controlling the rotational speed of a capstan motor in a video tape recorder or the like. Generally speaking, magnetic encoders are used for

positional or speed control in factory automation (FA) equipments, such as servomotors, robots and the like, or in office automation (OA) equipments, such as printers and copying machines. In recent years, there has been an increasing demand for improving the accuracy of such equipments. In general, the magnetic encoder includes a magnetic recorder and a magnetic sensor disposed in opposition to the magnetic recorder. The magnetic recorder comprises a non-magnetic substrate and a recording medium which is a permanent magnetic material coated on the peripheral or flat surface of the non-magnetic substrate. The recording medium is magnetized in a multipolar fashion at a magnetizing pitch λ to form at least one magnetic signal track.

A hard disk drive (HDD) is a digital data storage device that writes and reads data via magnetization changes of a magnetic storage disk along concentric information tracks. During operation of the HDD, the disk is rotated at speeds in the order of several thousand revolutions-per-minute (RPM) while digital information is written to or read from its surface by one or more magnetic transducers. To perform an access request, the HDD first positions the sensor and/or write head, also referred to as „read/write head", at the center of the specified data track of the rotating disk.

During operation of the HDD, the read/write head generally rides above the disk surface on a cushion of air, caused by an „air bearing surface", that is created by the movement of the disk under the head. The distance between the read/write head and the disk surface while riding, or partially riding, on the air cushion is referred to as the „flying height" of the head. Further, the head is carried by a „slider" which is supported by hydrodynamic lift and sink forces. These lift forces are given by the interaction of air streaming underneath the surface structure of the slider.

To build encoder applications with high resolution, it is important to minimize the gap between the sensor and the information track.

As the air bearing surface varies with the rotation speed, using air pressure as with the HDD applications is not possible if the variation of the relative movement is too high.

The known optical encoders are limited to a small temperature range due to high sensitivity of the used sensors to temperature changes. The resolution of these encoders is also very sensitive to dust and humidity of the environment.

Hall sensors are very sensitive to temperature changes and thus can also not be used in a wide temperature range as required in the field of automotive applications, industrial applications or the like.

Summary of the Invention

It is therefore an object of the present invention to provide a high-resolution magnetic encoder system that overcomes the disadvantages of the prior art systems.

This and other objects and advantages are achieved by the system disclosed in claim 1 and the methods disclosed in claims 10 and 11.

Advantageous embodiments of the invention are disclosed in the dependent claims.

Brief Description of the Drawings

The invention will in the following be described in more detail in conjunction with the drawings, in which

Fig. 1 schematically depicts an embodiment of the inventive magnetic encoder;

Fig. 2 schematically shows how a latent magnetic image is transferred from a contact stencil mask by ion irradiation;

Fig. 3 shows the activation of the latent magnetic servo patterns by external magnetic fields; and

Fig. 4 schematically shows how the activated servo patterns of Fig. 3 can be read out by a magnetic sensor.

Detailed Description of the Preferred Embodiment

The rotary magnetic encoder system of the present invention uses a magnetic media on a substrate and a magnetic sensor. In a preferred embodiment, the magnetic medium is a magnetic layer deposited on a substrate. This substrate must be rigid and can be selected from the group consisting of plastics, ceramic, silicon and glass. An overcoat layer, selected from the group consisting of layers of DLC, C_xN_y, BN_x, cBN, B_xC_y, B_x-C_y-N_z gradient layer, SiN_x, SiC, TiN, WC, AlO_x and the like, and preferably being a DLC-layer (Diamond Like Carbon layer) covers the magnetic medium and will help to adjust the distance (gap) between the at least one magnetic track provided on the magnetic medium and the magnetic sensor. In a preferred embodiment, the magnetic sensor is a GMR (Giant Magnetic-Resistive) or a TMR (Tunneling Magnetic-Resistive) sensor, and can as well be covered by, e.g., a DLC-layer.

Figure 1 shows a preferred embodiment of the inventive magnetic encoder system 2. A magnetic sensor 4 is mounted on a suspension 6 fixedly arranged on a substrate 8 above a magnetic medium 10. In the present example, the magnetic medium is a

rotating disk 12 on which a magnetic layer 14 is deposited. The magnetic layer 14 carries at least one magnetic track 16. The substrate 8 may be, e.g., an electronic board or the like. The rotating disk 12 is mounted on a shaft 18 with at least one ball bearing 19. To stabilize the mechanical tolerances, the shaft can be reach up to the top of the housing, where a second ball bearing (not shown) is mounted. The shaft 18 is connected to the external device (not shown) the rotation movement of which is to be evaluated, e.g., a motor or the like.

It has to be mentioned that the sensor 4 is adapted to perform a relative movement with respect to the magnetic medium 10, i.e., either the substrate 8 or the magnetic medium can be rotated or moved.

A rotation of the substrate 8 to which the suspension 6 is attached may be difficult due to the evaluation unit and the respective leads attached to the substrate, however, in case the respective connections are realized without actual physical leads, e.g., wireless, this can be done very easily.

The sensor 4 moves in close contact to the surface of the magnetic medium 10 that is protected by a hard cover (overcoat) layer 20, that is selected from the group consisting of layers of DLC, C_xN_y, BN_x, cBN, B_xC_y, B_x-C_y-N_z gradient layer, SiN_x, SiC, TiN, WC, AlO_x and the like, and preferably is a DLC layer. The whole system may be encapsulated by a housing 22.

It has to be mentioned that the suspension can as well be attached to the housing 22 instead of the substrate 8.

The overcoat may be covered by a lubricant layer (not shown), selected from the group consisting of long chain hydrocarbons, MoS, MoSe, Teflon, perfluoropolyether (PFPE), and the like.

The modulation of the magnetic field leads to a modulation of the resistance of the GMR element. If a constant current is applied, the output voltage has a sinusoidal characteristic. When using incremental encoders it will be possible to count maxima or zero points. Extrapolation for higher resolutions is however possible. When using absolute encoders, it will have multiple tracks which represent a code.

Since optical encoder disks for relative and absolute angle determination are limited in resolution and are facing problems when they are exposed to elevated temperatures as occurs for instance in automotive applications, it is desirable to create a planar disk with magnetic encoder features that can be read out by contact to a read sensor.

It is known that by ion irradiation magnetic properties of magnetic films such as CoPt multilayers can be modified. In such a way the irradiated areas can be magnetically softened. This process can be precisely controlled by the ion dose applied. As shown in Fig. 2, a servo pattern 24 which is defined in a contact stencil mask or a resist mask 26 can be transferred into a latent magnetic pattern in the magnetic coating of an encoder disk 28 by applying ion irradiation 30.

As known from patterned media fabrication using ion beams, the disk surface remains unmodified under adequate irradiation conditions. In contrast to the patterned storage media the latent magnetic patterns of the encoder disk are not transferred into a magnetization pattern by a single island write process but are activated by large area homogeneous magnetic fields that develop all the magnetic patterns in parallel. As shown in Fig. 3, a magnetic field 32 saturates the full disk 28 in one direction. Subsequently, a smaller counter magnetizing magnetic field 34 is applied which reverses only the irradiated islands, thereby activating the full servo pattern on the entire disk 28.

The ion beam technology switches from longitudinal to vertical recording. Therefore, the size of a magnetic bit can be lowered while still having a big magnetic field.

Because the disk surface remains unmodified throughout the irradiation and magnetization procedure, a magnetic read sensor 36 in contact with the rotating disk 28 can read very small magnetic servo structures 24 as shown in Fig. 4.

The near field sensing allows to reduce the servo features to allow for finest resolution. The magnetic coercivity of the servo features that is adjusted during the ion irradiation is still high enough to allow for thermal stability of the pattern even at elevated temperatures.

An additional advantage is that all encoder servo features are generated as latent patterns and then activated simultaneously in a simple magnet, thereby superseding any costly servo writing procedures.

Since the servo patterns are activated by an external magnet, the track width of the pattern can be large compared to the read sensor dimensions, giving a large tolerance for radial runouts. The servo pattern is defined with the mask layout, therefore there are no dead or undefined sectors like in sequential writing at the start and stop sectors.

The inventive system has the advantage that, due to the GMR technology used, high temperature resistivity/stability can be achieved.

Further advantages of the proposed solution are that because of the low weight of the sensor and the flexible suspension, which as well can be protected by a DLC-layer, the system is highly

shock- and vibration-resistant since there is no need of precisely aligned optical elements inside the encoder package, and that high signal amplitudes can be achieved due to wide magnetic tracks, since the resolution of the encoder is not limited by the radial dimension of the magnetic pattern and the low spacing between sensor and magnetic medium.

Furthermore, the system works in start-stop-mode and with varying angle velocities (rpm). In a HDD a constant rotation speed is necessary. In an encoder the speed varies between zero and a maximum and the direction of motion can also change. Therefore an ABS (air bearing surface) adjusting the flight height cannot be designed for encoders. For contact reading like in the encoder according to the present invention, the ABS is only a question of minimizing the wear. The ABS is not necessary to adjust the flight height.

In addition, absolute and differential signals are provided and the magnetic patterns can be produced with high areal density, which leads to a very high resolution.

Further advantages are that the GMR sensitivity is not affected by humidity or dusty environment and that the encoder system is scalable to higher resolution. Due to the ion beam technology and the low magnetic spacing the magnetic bit can be very small. Enlarging the bit size, which lowers the resolution, is not an issue. Therefore the encoder resolution is scalable over several orders of magnitude.

CLAIMS

1. A high-resolution magnetic encoder system (2), comprising a magnetic resistive sensor (4) mounted on a fixed suspension (6) above a magnetic medium (10), said suspension (6) being attached to a substrate (8) or a housing (22), and said magnetic medium (10) carrying at least one magnetic track (16), wherein said sensor (4) is adapted to perform a relative movement with respect to and in close contact to the surface of said magnetic medium (10), which is protected by a overcoat layer (20).

2. Magnetic encoder system according to claim 1, wherein said magnetic media (10) is a magnetic layer (14) deposited on a rotating disk (12).

3. Magnetic encoder system according to claim 1 or 2, wherein said overcoat layer (20) is selected from the group consisting of layers of DLC, C_xN_y, BN_x, cBN, B_xC_y, B_x-C_y-N_z gradient layer, SiN_x, SiC, TiN, WC, AlO_x and the like.

4. Magnetic encoder system according to any one of claims 1 to 3, wherein said substrate (8) is an electronic board.

5. Magnetic encoder system according to any one of the preceding claims, wherein said magnetic sensor is a read/write magnetic head.

6. Magnetic encoder system according to any one of the preceding claims, wherein said magnetic sensor (4) is a GMR or a TMR sensor.

7. Magnetic encoder system according to any one of the preceding claims, wherein the system is encapsulated.

8. Magnetic encoder system according to any one of the preceding claims, wherein said magnetic media (10) is a planar disk carrying magnetic encoder features that can be read out by a magnetic read sensor (36).

9. Method of forming a high-resolution magnetic encoder system (2), wherein a magnetic sensor (4) is mounted on a fixed suspension (6) above a magnetic media (10), said suspension (6) being attached to a substrate (8), and wherein said sensor (4) performs a relative movement with respect to and in close contact to the surface of said magnetic media (10), said magnetic media (10) being protected by a hard cover layer (20).

10. Method for fabricating a magnetic encoder disk (10), comprising the steps of

- providing a servo pattern (24) in a contact stencil mask (26);
- transferring said servo pattern (24) into a latent magnetic pattern in the magnetic coating of said encoder disk (10) by ion irradiation (30); and
- activating said latent magnetic pattern by applying a magnetic field saturating the full disk (10) in one direction, and subsequently applying a counter magnetizing field, thereby reversing the features irradiated through said mask (26).

11. Method according to claim 10, wherein said reversed features are read out by a magnetic read sensor (36) in contact with said magnetic encoder disk (10).

ABSTRACT

A high-resolution magnetic encoder system, comprising a magnetic sensor mounted on a fixed suspension above a magnetic medium is provided, wherein the magnetic medium carries at least one magnetic track. The sensor moves in close contact on the surface of said magnetic medium, which is protected by a hard cover layer.

(Fig. 1)

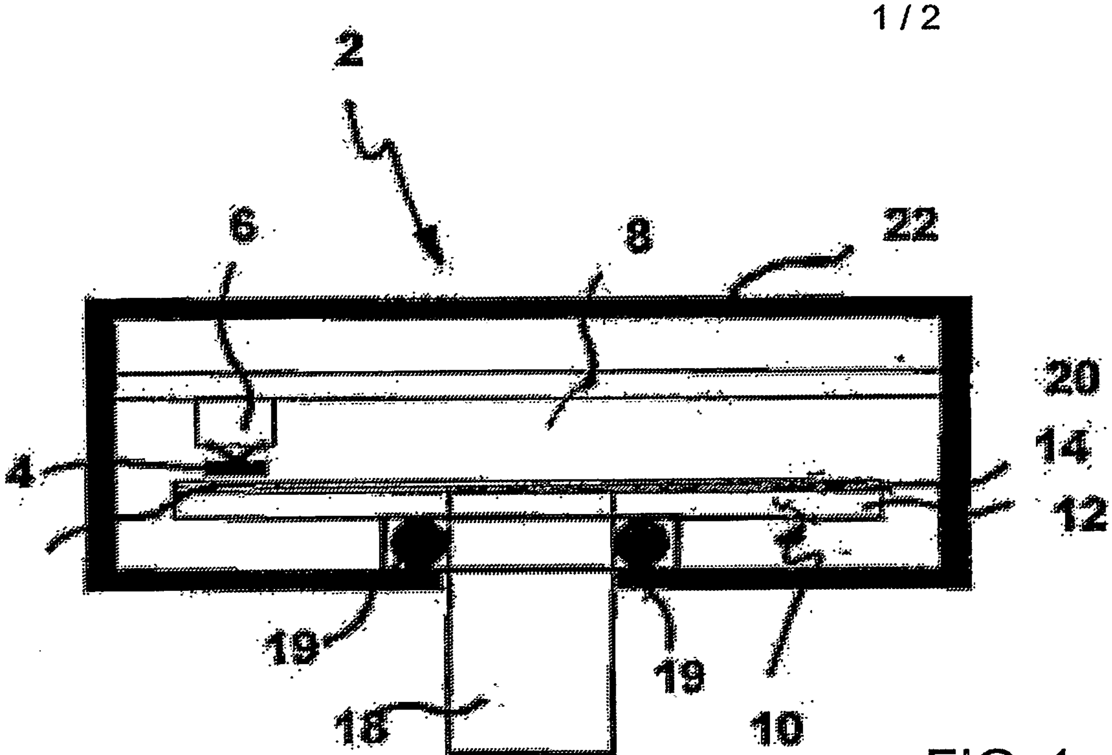

FIG. 1

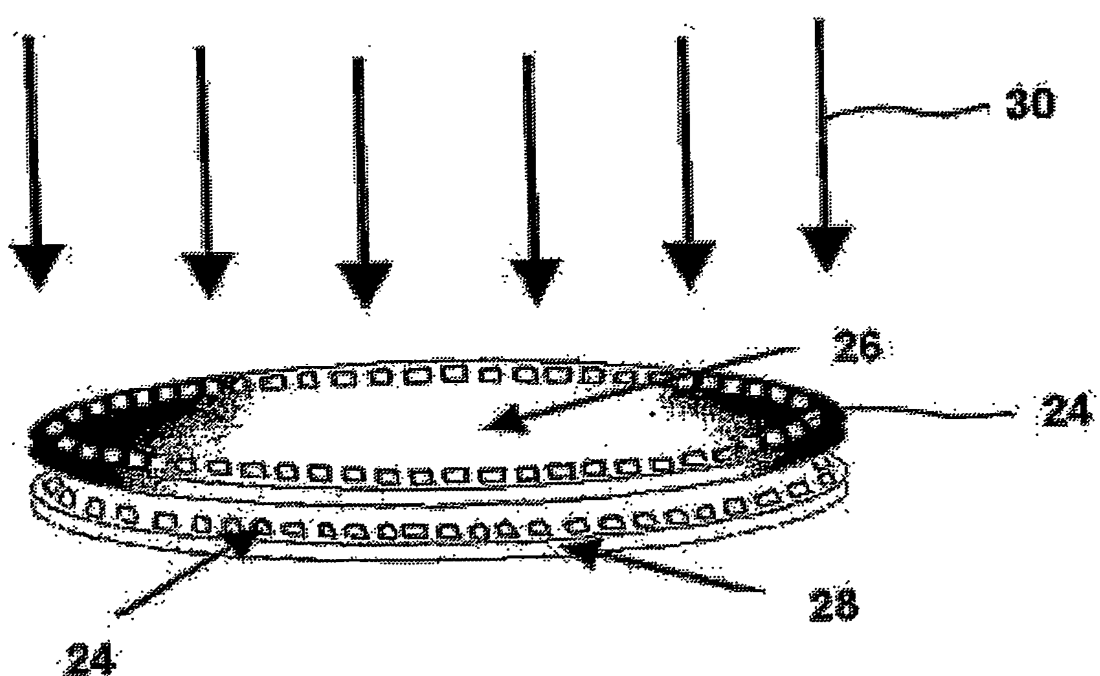

FIG. 2

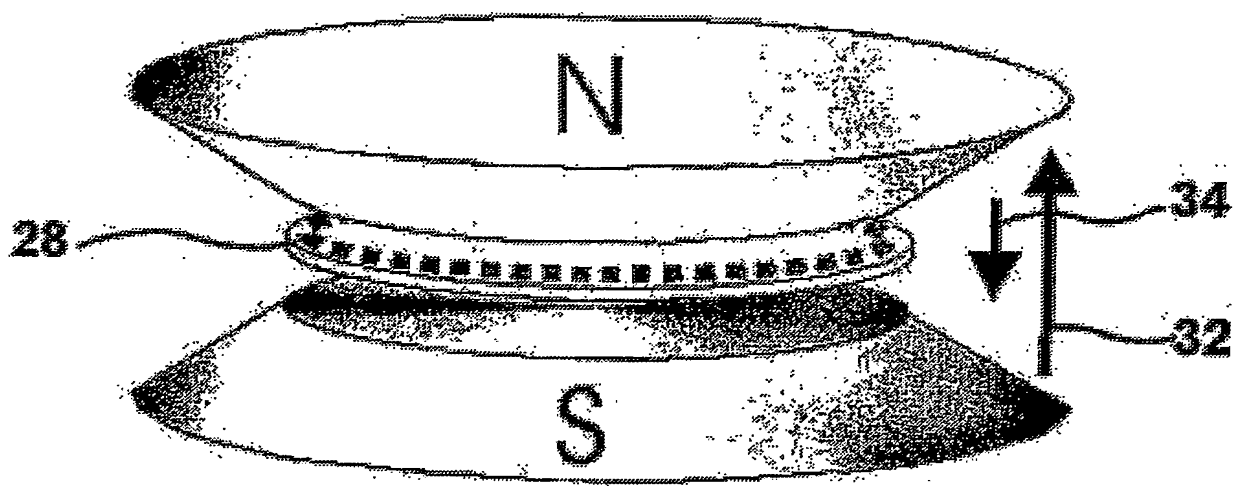

FIG. 3

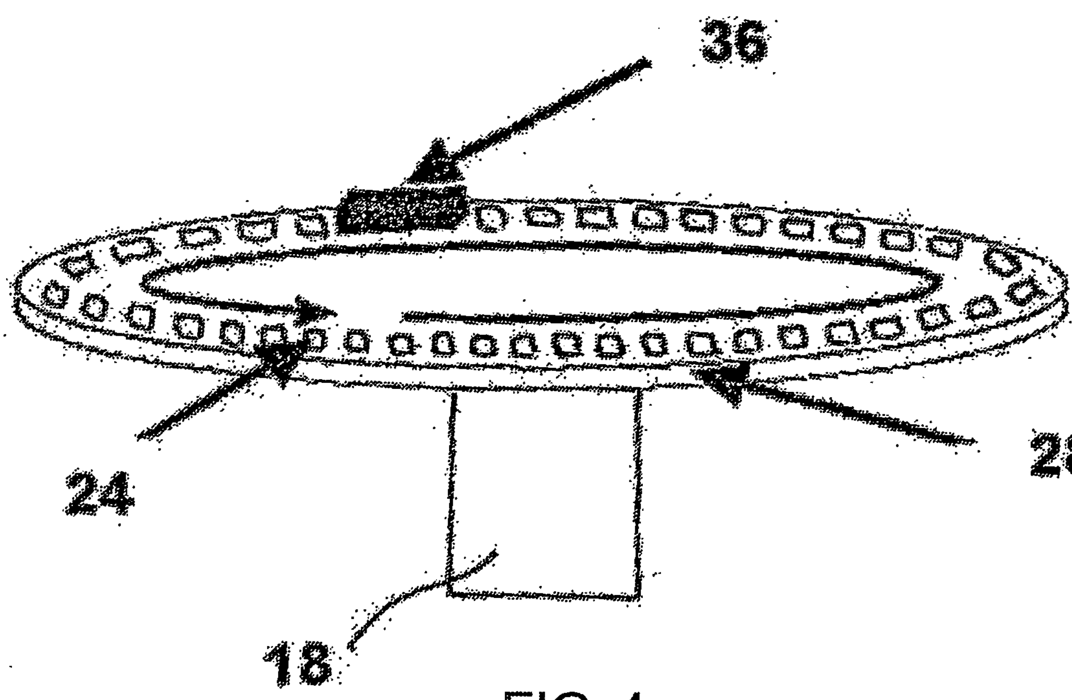

FIG. 4